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Downy Mildew of Hops

By

G. R. Hoerner,

Agent, United States Department of Agriculture, Bureau of Plant Industry, Division of Drug and Related Plants

Oregon State Agricultural College
Extension Service

Corvallis, Oregon

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Paul V. Maris, Director
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INTRODUCTION

DOWNY mildew is now generally recognized as the most serious disease of hops in the world. Just where it started no one knows. Neither is it known just how it got into the commercial hop centers of Europe and America. Although it was found on both native and cultivated hops in Japan in 1905 and on wild hops in Wisconsin in 1907, nothing more was heard of the trouble until 1920 when it was discovered in hop plantings in England. Developing rapidly in England, it appeared on the continent of Europe, causing great destruction in all the leading hop-growing centers. Finally in 1928 it was again reported in America on wild hops in Manitoba, on cultivated hops in New York State, and in the commercial fields of British Columbia, where a severe outbreak occurred. It was not recognized in the State of Washington until 1929 nor in Oregon until 1930, when it was widespread in the western parts of both states, causing considerable damage in several localities, particularly early in the season.

In every country where this new disease has appeared it has taken firm root and the outbreaks generally have increased in extent and severity following its first appearance.

DISTRIBUTION OF THE DISEASE ON THE PACIFIC COAST

There are approximately twenty-three thousand acres of all varieties of hops in the states of California, Oregon, and Washington. A complete inspection of this entire acreage has not been attempted. A fairly representative survey of the presence of the disease, however, has been possible by compiling information from every available source.

In 1930 downy mildew was reported from Lewis and Pierce counties, Washington, and from Benton, Clackamas, Lane, Linn, Marion, Polk and Yamhill counties, Oregon.

In 1931 a more complete survey of hop-growing areas of Pacific Coast states showed downy mildew infection on hops again in these same localities and in Jackson, Josephine, and Washington counties of Oregon, as well. In 1931 the number of individual plantings found to be infected was considerably larger than in 1930 and a much larger part of the hop-growing area seems to have been invaded by the disease. This situation may be due in part to the fact that growers generally were better informed of the symptoms of the disease and as a result more able readily to recognize its presence and in part to the fact that both growers and officials were on the alert to detect and report its occurrence. There is no doubt, however, that in a year's time the disease has either spread rapidly or appeared suddenly over a very extensive area.

To date the disease has not been found in the hop-growing districts of Yakima county, Washington, or in the state of California. That these last-named sections have remained apparently free of the disease may mean that it has not so far been introduced; that if it has been introduced climatic conditions have not been favorable to its spread or continued existence; or that infected plants, if present, have been so few and so isolated that the disease has escaped notice.

VARIETIES AFFECTED BY DOWNY MILDEW

When downy mildew first appeared on the Pacific Coast both Early Clusters and Late Clusters were found infected. Fuggles were thought to be immune. It has since been learned that the principal commercial varieties of hops grown in the Pacific Coast States—namely, Early Clusters, Late Clusters, Red Vines, and Fuggles—are all subject to infection.

In greenhouse seedling experiments there is little noticeable difference in the degree of susceptibility of these four varieties. Seedlings from Late Clusters seeds which were grown in California were readily infected.

Under field conditions, however, Early Clusters generally appear most susceptible, Late Clusters perhaps appear somewhat less susceptible, and Fuggles, while not immune, are evidently resistant. Only one commercial planting of this variety has been found seriously damaged.* One very limited planting of European hops has been found in Oregon that apparently was not infected even though it was located in a heavily infected yard of Late Clusters. This resistant hop has distinct commercial limitations but may prove to be a valuable parent in producing mildew-resistant hybrids of commercial value.

CAUSE OF THE DISEASE

Hop downy mildew is caused by a fungus† which for all practical purposes is confined to hops. As far as is now known, all parts of the plant except the seed may become infected. The fungus gains entrance into the plant through the invisible breathing pores located all over the green parts of the plant. Within a few days after infection, under favorable conditions, a tremendous number of very minute spores (seeds of the fungus) may be produced on the surface of infected parts of the plant above ground. Thick-walled winter spores are formed within the tissues of infected parts of the vines where they remain alive over winter in the hop trash on or in the ground. Portions of the fungus may also remain alive in the buds on the crown, in the tissues of the crown itself, or in the roots of infected plants.

SYMPTOMS OF DOWNY MILDEW

Beginning sometimes as early as the first week in March spike-like infected growths arise from the crown among normal, slender shoots. These spikes are commonly pale green or silvery gray in color, rigid, stocky and stunted. They are usually brittle and when broken are found to be brown within. The leaves of these spikes are usually small and close together with the edges cupped downward. A yellowish-green area first appears at the bases of the leaves on the spikes. In a few days the undersides of these discolored leaf areas, the leaf stalks, and the shoot are covered with a dark, downy mass of summer spores. The spores show up first on the lowest leaves and finally on the leaves at the tip of the spike. Before the spores appear, infected leaf stalks and other infected parts of the vine often present a grayish blistered appearance.

*This yard was located in Pierce county, Washington.

†*Pseudoperonospora Humuli* (Miyabe and Takahashi) Wilson.

The tips of the normal shoots or of the branches arising from them may become infected and transformed into spikes similar to those arising from the crown except that they may be longer and more leafy and the infections seem to spread from the tips downward. Infections often take place at the joints along the stems.

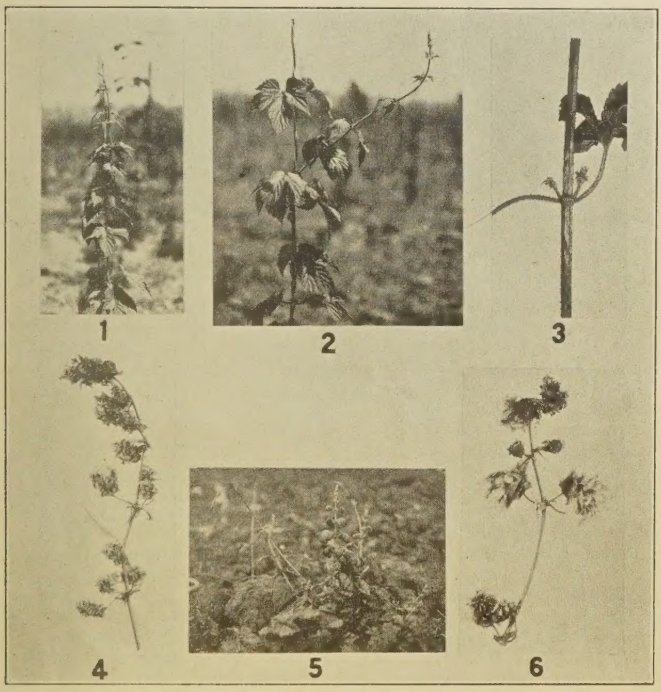

Figure 1. EFFECTS OF DOWNY MILDEW ON HOPS. (*Original.*)

(1) Terminal Spikes. (2) Lateral Spike. (3) Infection at joint of stem showing blighted lateral buds. (4) and (6) Infected Cones. (5) Basal Spikes.

Both male and female flowers may become diseased. When seriously attacked both turn brown, shrivel, dry up, and at times drop. If very young cones are attacked they cease to grow and become hard and brown. If older cones are affected they become brown and often do not develop properly. On all infected flower parts dark masses of summer spores may occur.

Leaves of all ages on either spikes or normal vines may become infected from summer spores developed on other parts of the plant. The first evidence of this type of leaf infection is the appearance of pale, more or less angular spots on the upper surface. These spots soon become brown and angular and may run together to form large dead areas. On the under surfaces of these spots dark masses of summer spores are produced.

HOW THE DISEASE IS SPREAD

The summer spores serve to spread the disease throughout the growing season. They are undoubtedly carried by winds and it is quite possible that they may be spread by rain from infected portions of a plant to healthy parts of the same or neighboring plants.

The winter spores may germinate in early spring and are thought to be responsible for much of the early-spring infection of developing shoots.

The disease may be spread by transplanting infected nursery plants or perhaps by using cuttings from infected plants in which portions of the fungus may be hibernating.

Moderate temperatures are favorable and damp weather absolutely necessary for the spread of downy mildew. The fungus does not produce spores readily, if at all, when the air is dry and the spores cannot cause infection if moisture is not present. Rains, fogs, dews, cloudy days and very humid air conditions, particularly on low-lying yards where air drainage is poor, favor spore production and infection. In the Pacific Northwest, as a rule, the greatest amount of damage will generally take place during the spring months. The hot dry conditions prevailing in this section from the middle of June to early September are unfavorable to the spread of the disease. With the recurrence of rain in September and October, however, the disease may again develop with surprising rapidity, infecting the crop in the course of harvest and continuing to spread until the vines are killed by frost.

EXTENT AND NATURE OF LOSSES FROM DOWNY MILDEW

In Oregon, growers' estimates of reductions in yields due to downy mildew range from nothing to one hundred percent. The average for the state, based on reports submitted in 1931, was from fifteen to twenty percent. In severe cases all shoots arising from an infected hill may be spikes. Spiked shoots are non-climbing. Badly infected shoots are severely checked in growth. New laterals may have to be trained up or new shoots from the crown used in order to produce a crop. This practice delays the ripening period and may subject the ripening cones to fall infection before they can be harvested. Infections at the joints of the vines either spike or kill outright the buds arising at these points. Diseased male flowers fail to produce pollen and female flowers fail to produce cones. If the crop is picked too early in order to avoid possible rainy weather and danger of mildew on the cones both the size and the quality of the crop may be affected. If cones are infected late in the season they may be discolored sufficiently to reduce the market value of the dried hops or the crop may be rendered entirely unfit to pick.

RECOMMENDATIONS FOR CONTROL

Extermination of the disease is not considered possible but there is no reason to fear that downy mildew will prevent profitable hop production in hop-growing areas of Oregon and Washington even where the disease is at present firmly established. The disease can be controlled by spraying and other field practices. A tentative spray program and other control suggestions are included in this bulletin.

Figure 2. LEAVES INFECTED WITH DOWNY MILDEW. (*Original.*)

(1) Upper surface of leaf showing light-colored area invaded by the fungus through the leaf stalk. (2) Under surface of the same leaf showing the dark covering of summer spores. (3) Upper surface of leaf showing dead areas from scattered infection by summer spores.

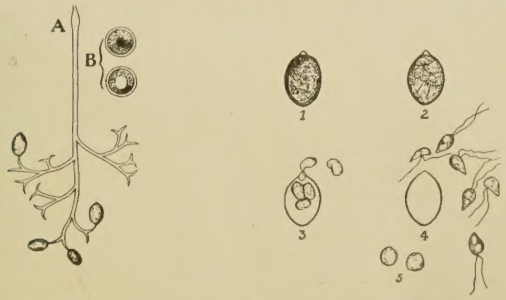

Figure 3. THE HOP DOWNY MILDEW FUNGUS. (*Greatly magnified. After Salmon.*)

On the left (A) Branched stalk bearing summer spores. (B) Two resting spores taken from an infected leaf. On the right (1) A ripe summer spore. (2) Contents beginning to divide. (3) Separate parts have developed and are beginning to emerge. (4) These, having developed swimming-hairs, move about rapidly in the water. (5) After a short period they come to rest, lose their swimming-hairs and infect a hop leaf or cone.

Control measures of necessity add to the cost of production and there is need for continued experimental work to determine the most effective and at the same time the most economical control program which can be devised for the Northwest.

In order to avoid the expense of spraying and perhaps other control practices, hop breeding and selection work should be continued until one or more commercially desirable hop varieties are developed which will not be seriously affected by the disease.

It may require several years to test thoroughly various methods, materials, and equipment before growers can be finally advised as to the best control program. Active grower cooperation will be of great assistance in bringing about the desired results in the shortest possible time. As the work progresses growers will be advised of any desirable changes in the control program as suggested for 1932.

SUGGESTIONS FOR 1932

Wild hops. Escaped or volunteer hops about the fields, in fence rows, and on buildings and neglected vines growing on the guy wires are subject to attack and provide a constant source of infection for commercial plantings. They should be destroyed.

Field clean-up. Vines should be cut, raked, and burned as soon after picking as possible without injury to the plants, in order to prevent the soil about the hills from becoming contaminated with the winter spores.

Pruning. Little is known about the effect of pruning practices on the disease, but it is thought that annual spring pruning will probably remove most of the portions of the fungus that might be present in the crowns. If the hills are left uncovered after pruning until the vines are trained, perhaps some infection may be avoided since it seems likely that developing shoots will be prevented from coming in contact with much contaminated soil that might be the cause of spike formation.

Crown treatments. The method of attempting to control basal spike formation by putting chemicals on the crowns is not advised until further experimental evidence is at hand to justify the recommendation. Extensive trials are under observation.

Early training. From the standpoint of mildew control, early working of the yard is thought to be desirable. An extra large number of vines should be trained up as soon in the spring as possible. By this practice shoots are prevented from remaining long on the ground where moisture conditions are favorable to infection from winter spores or from the summer spores from neighboring spikes. If the trained-up vines become infected and have to be removed it is possible to use the extra vines and still obtain a crop. In early worked yards, even if an entire stand of new shoots has to be trained up from the crown because the first stand was destroyed by mildew, a crop may still be matured in good season.

Stripping. Stripping should be completed as soon after the first training as practicable and with as little injury as possible. Sheep may be used satisfactorily if a sufficient number are used on a given acreage and they are confined to a limited area and forced to do a good job. Leaves left near the ground are always more likely to get mildew than those higher up.

Hill clean-up. Clean cultivation throughout the season is desirable with particular attention being paid to prompt and continuous removal of suckers.

Removal of spikes. Yards should be patrolled regularly from the time the first shoots appear in the spring. Spikes should be collected, removed from the yard and burned. Workers who are plucking spikes should not be engaged in suckering, stripping, or training as they would directly help to spread the disease.

SPRAYING AND DUSTING FOR PROTECTION

The purpose of using fungicides either in dry or liquid form is to protect healthy plants from becoming infected and not to effect a cure after infection has already taken place. The ideal situation would be to keep all parts of the plant covered with a fungicide at all times, to insure protection during periods favorable to spore formation and germination. With a plant that grows as rapidly as hops this is practically impossible. We are forced for reasons of economy to suggest the least possible number of applications at periods that are apt to be favorable to infection and when there is considerable new vine growth that is unprotected. The amount of disease present in each yard and the prevailing moisture conditions will determine largely the timing of applications. Unfortunately definite spray dates cannot be accurately foretold for each grower because weather conditions and the amount of mildew present alike vary from season to season and in different localities.

Growers will have to use their best judgment in applying these general recommendations to their own conditions.

In the event of the sudden development of a serious infection in one part of a yard growers should spray that portion of the yard first before proceeding to protect other portions of the yard some distance from the point of heaviest infection.

Dusting. Dusting for the control of hop downy mildew is still in the experimental stage and is not recommended until further information is at hand respecting its value as compared with liquid sprays. Extensive trials are under way.

Spraying equipment. No particular type of spraying equipment is at present recommended. Good agitation and sufficient pressure to cover thoroughly the undersides of the leaves to the full height of the vines with a fine, misty spray are essential.

Spraying. Bordeaux mixture has definitely proved its effectiveness in both Europe and America. Our present recommendation for the Pacific Northwest is to use Bordeaux mixture 4-4-50 with spreader as follows:

1. As soon as the vines are first trained. It is important to cover leaves and shoots thoroughly because the scales along the stalk readily hold moisture in which summer spores can germinate. Try to cover the undersides of the leaves since practically no infections occur through the upper leaf surface.

2. When vines get to the cross wires or to the tops of the poles in pole yards (10 to 14 feet tall).

3. Just before the female flower buds open (before the "brush" stage is reached). Do not spray in full bloom if it can be avoided as some injury is apt to result.

4. If weather conditions especially favorable to the spread of mildew occur during any part of the growing season, other applications may be necessary.

There is strong evidence that spraying in the hot sun or on days following very cold nights is likely to cause injury. Some spray injury can be expected under some conditions from the recommended strength of Bordeaux mixture. While unsightly, this injury is seldom serious. Experiments to reduce the strength of Bordeaux mixture or to develop substitute materials, particularly for use on the ripening cones, have not proceeded far enough as yet to warrant a change in the 1932 recommendations. Spreader has been found necessary for good coverage. When spraying use a fine mist and remember that every spot left uncovered is a possible point of infection.

HOW TO PREPARE BORDEAUX MIXTURE 4-4-50

1. Dissolve 40 pounds of copper sulfate (bluestone) in 40 gallons of water or at the rate of 1 pound per gallon. If tied in a gunny sack suspended so that the sack just touches the water, the bluestone will dissolve over night. Use a wooden barrel or concrete container as bluestone will corrode metal.

2. Soak 60 pounds of fresh hydrated lime in 40 gallons of water or at the rate of 1½ pounds per gallon or slake 40 pounds of quick-lime (fresh stone lime) and fill up with water after slaking, using 40 gallons altogether.

3. Start filling the spray tank with water.

4. Stir up the milk of lime and add 8 gallons of it to the tank for every 100 gallons the spray tank holds. Put the lime water into the spray tank through a strainer.

5. After the tank is about ¾ full of water and while the agitator is still running, stir up the stock solution of dissolved bluestone thoroughly and begin to add this slowly at the rate of 8 gallons for every 100 gallons the spray tank holds.

6. Add spreader with agitator still running.

7. Start spraying at once. Bordeaux mixture performs best if applied as soon as mixed. After standing a few hours it loses its best qualities. The stock solutions of lime and bluestone do not deteriorate so long as they are not mixed together.

SPREADERS

Rosin soap spreaders are the most highly effective of all the many types of spreaders that have been tried by the writer up to 1932 for use with Bordeaux mixture on hops. They have a decided curdling action on Bordeaux mixture, however, and if they are improperly prepared they may induce burning of the sprayed vines and may clog the nozzles of the

sprayer. If used in cone sprays late in the season many growers are convinced that these rosin soap spreaders impart an objectionable odor to the stored hops. A simplified formula is presented for those who wish to use this type of spreader.

Rosin Soap Spreader

Water	6 gallons
Potash lye	4 pounds
Fish oil	6 quarts
Rosin	10 pounds

Dissolve the potash lye in the water and heat to boiling. Add the fish oil and boil vigorously for 15 to 20 minutes, stirring meanwhile. Then add the rosin, preferably broken into small lumps, and continue boiling for 15 or 20 minutes. Use at the rate of one quart to each 100 gallons of spray.

By means of experimental work in the greenhouse it has been determined that two other spreaders are also efficient when used with Bordeaux mixture on hop foliage. Formulae are presented herewith:

Skim-Milk Spreader

Skim milk	1 gallon
Hydrated lime	½ pound

The lime should be added to the milk and vigorously stirred before it is added to the Bordeaux mixture. If sweet milk is not available, sour milk may be used. Use at the rate of 1 gallon to each 100 gallons of spray.

Powdered Milk Spreader

Skim milk powder	1½ pounds
Hydrated lime	2 tablespoons

The hydrated lime should be added to a little water in a pail, the powder added to the water, and the whole stirred vigorously before being added to the Bordeaux mixture. Use the amount of the foregoing formula to each 100 gallons of spray.

Neither of these skim-milk spreaders curdles Bordeaux mixture. They are cheap, easily prepared, will not induce foliage burning, will not clog the sprayer nozzles, and since they do not contain fish oil will probably not impart an unfavorable odor to stored hops even if used with sprays applied to the cones late in the season.

N. B. More extension work with Skim-milk and Powdered Milk spreaders under variable field conditions indicates:

1. The amount of skim-milk used should be increased to 2 gallons to each 100 gallons of spray
2. Powdered milk is not uniformly satisfactory and its use should be abandoned until further information concerning its limitations can be obtained.